FACTORS INFLUENCING NONTARGET BIRD OCCUPANCY OF RESTORED WETLANDS IN CALIFORNIA'S CENTRAL VALLEY

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ABSTRACT: Intensively managed restored wetlands and flooded croplands of California's Central Valley support millions of wintering waterbirds. While the benefits to wintering waterfowl are well documented, the effect of intensive management on birds at other times of the year is less clear. Practices such as drainage, mowing, disking and burning may be a nuisance to these nontarget birds at best or life threatening at worst. Alternatively, irrigation over the summer may create habitat that might otherwise be lacking in the dry season. Our objective was to assess the influence of management, adjacent land use, and habitat characteristics on the richness, diversity, and occupancy of birds other than waterfowl in the spring and summer. We conducted 640 bird surveys on restored wetlands managed at varying levels in 2008 (4 April–30 July) and 2009 (19 April–16 July) and used likelihood-based modeling to evaluate occupancy and the relative importance of intensity of management and various environmental factors. Management was not the most important predictor of the richness, diversity, or occupancy of nontarget birds in the summer; rather, variables such as wetland size, vegetation composition, and landscape characteristics were more important for most bird guilds. Contrary to the commonly held view that restored wetlands in California's Central Valley support only wintering waterfowl, they also support a diverse avifauna year round regardless of how they are managed. Bird occupancy and diversity in restored wetlands may be enhanced by creating and maintaining large, complex mosaics of vegetation.

Each year California's Central Valley hosts the majority of the Pacific Flyway's wintering waterfowl (Gilmer et al. 1982). Restored wetlands provide critical food and habitat for winter visitors, and there is broad support for programs and initiatives geared toward increasing the extent of wetlands in winter (CVJV 2006). Far less emphasis is placed on the role restored wetlands play in supporting summer breeders, migrants, and year-round residents.

Greater than 95% of all depressional wetlands and 98% of riparian wetlands in California were destroyed between 1800 and 1980 (Dahl 1990, CVJV 2006, Garone 2011, Duffy et al. 2016). The passage of the Swamplands Act in 1850 and subsequent revisions led to extensive alterations to natural hydrology through the creation of reservoirs and channelization of the Central Valley's main rivers. Restoration has been intended to replace the thousands of acres of wetland lost to agriculture and human settlement. Most managed restored wetlands target wintering waterfowl and therefore receive most of their water in the fall and winter. Historically, however, much of the

Western Birds 47:138–150, 2016; doi 10.21199/WB47.2.3

Central Valley flooded in early spring and summer following peak flows in the Sacramento and San Joaquin rivers (Katibah 1984). The effects of this shift in the timing of flooding on wildlife occupying these wetlands in spring and summer are often overlooked. Greater scrutiny of the factors affecting spring and summer birds may help enhance biodiversity and expand their ecosystem service.

State legislation governing water appropriation and individual landowners' water rights constrain wetland management by limiting access to surface water. As a result, the Central Valley's restored wetlands are managed at widely different levels, from none to intensive (Duffy et al. 2011). Intensive management usually involves a series of hydrological manipulations including a drawdown of the water level in spring and irrigation in summer so seed-producing plants germinate in high density. This is followed by artificial flooding in the fall to coincide with the arrival of wintering waterfowl, a strategy often referred to as "moist-soil management" (Fredrickson and Taylor 1982). Moist-soil management also includes disking, mowing, burning, and herbicide application to maintain a desired composition of vegetation or to eliminate invasive plants and mosquitoes (Fredrickson and Taylor 1982, CVJV 2006). These activities typically take place between March and August when they may disturb breeding birds. Similar agricultural practices have been faulted for birds' avoiding a site and population declines (e.g., Beedy and Hamilton 1999, Zuckerberg and Vickery 2006). Alternatively, irrigation over the dry summer may attract opportunistic birds to managed wetlands.

Though managed wetlands support a wide variety of birds in the spring and summer (Kahara et al. 2012), it is unclear whether bird occupancy in those seasons is driven primarily by moist-soil management or other factors. Other studies suggest that characteristics of the site (e.g., Webb et al. 2010) and adjacent landscape (Sterling and Buttner 2011, Fleskes et al. 2012) play an important role, depending on the species. Our primary objective was to assess the relative importance of intensity of management, habitat at the site, and characteristics of the surrounding landscape in determining these wetlands' occupancy by and diversity of birds from April to July.

STUDY AREA

The Central Valley, about 650 km long and 120 km wide, covers 108,800 km^2 (Schoenherr 1992), ~26% of the total area of California. It may be subdivided into the Sacramento River sub-basin in the north and San Joaquin and Tulare sub-basins in the south (Figure 1). Its topography is relatively flat, elevations ranging from 120 m in the north and south to below sea level in the Sacramento–San Joaquin delta (Schoenherr 1992). Over 90% of precipitation falls from November to May. Air temperatures vary little through the valley; average July highs approach 38 °C at both Bakersfield in the south and Redding in the north, while average December lows at Bakersfield (2.9 °C) are only slightly warmer than at Redding (2.7 °C). Precipitation decreases from north (average 90 cm/year) to south (average 12 cm/year) and from east to west, because of the rain shadow of the Coast Ranges (Carter and Resh 2005). We used the three Central Valley sub-basins to categorize our study sites along the gradient of precipitation.

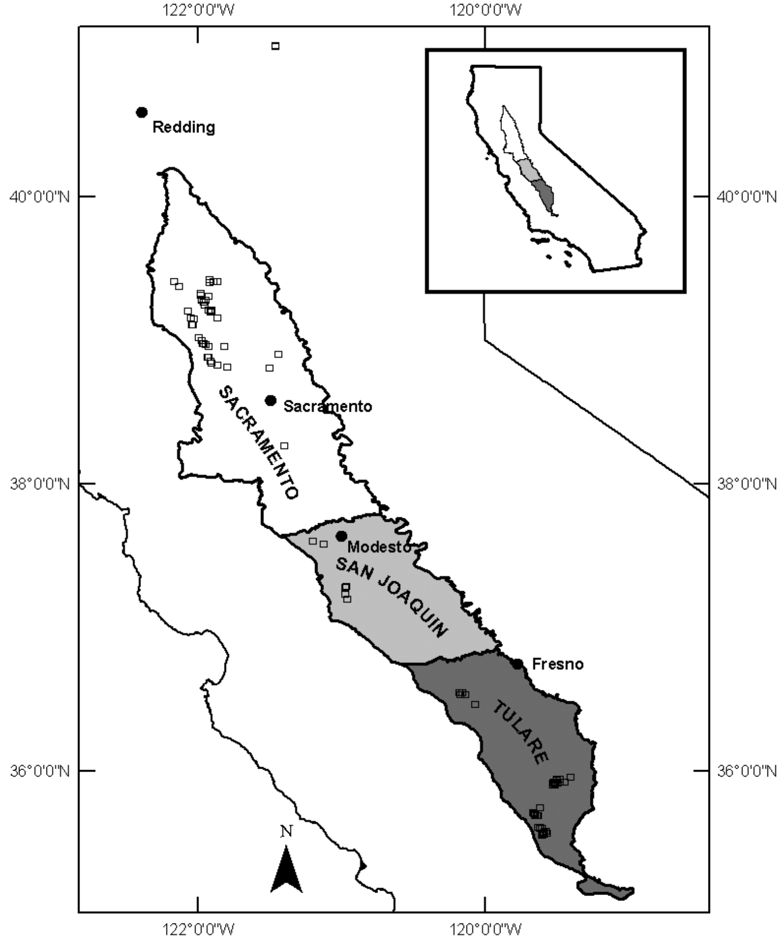

Figure 1. Location of 2008 and 2009 sampling sites (squares) in California's Central Valley, in the context of three major sub-basins, Sacramento (white); San Joaquin (light gray), and Tulare (dark gray).

Most of our study sites were wetlands restored under the Wetlands Reserve Program (WRP), a U.S. Department of Agriculture (USDA) conservation initiative established under the Food Security Act of 1985. The WRP gave private landowners the opportunity to restore, protect, and enhance wetlands on their property through a cost-share agreement with the USDA and applied only to converted former wetlands. The Agricultural Act of 2014 replaced the WRP with the Agricultural Conservation Easement Program (ACEP); however, WRP easements established prior to the enactment of ACEP remain valid for the duration of their contracts.

WRP easements are often subdivided into smaller manageable areas or "units" that are typically between 10 and 50 ha in size. Wetland units comprise a basin surrounded on all sides by levees 1–2 meters high to hold water. Troughs, islands, and sloughs are common design features for varying the topography and water depths within the basin while allowing water to be conveyed from inlets to outlets. When flooded, wetland units with varied topography promote the germination of a diverse assemblage of plants depending on their tolerance for duration and depth of flooding (van der Valk and Davis 1978, Fredrickson and Taylor 1982).

METHODS

From 10 April to 30 July 2008, we surveyed 60 units in 26 wetlands restored under the WRP and one unit in Kern National Wildlife Refuge. From 19 April to 16 July 2009, we surveyed 11 units in 11 WRP wetlands. Three sites were surveyed in both years.

For this study, we ranked wetlands by three levels of intensity of management according to assessments by biologists with the Natural Resource Conservation Service and interviews with land owners. Management at the highest level ("intensive") entailed a combination of moist-soil techniques including hydrological and mechanical manipulation every year since restoration. Wetlands managed at the intermediate level received some or all techniques of moist-soil management in at least 50% of the years since restoration. Unmanaged wetlands had never had any moist-soil management techniques applied to them since restoration. We also categorized wetlands by time since restoration, as relatively young (5 years or less since restoration at time of sampling) or relatively old (>5 years since restoration at time of sampling). Most wetlands ranged in age from 0 (restored within 12 months of our surveys) to 12 years.

Habitat Surveys

We distinguished uplands from wetlands by their preponderance of flood-intolerant plants and grasses. We subdivided wetlands, dominated by flood-tolerant plants, into four approximately circular concentric zones around the lowest elevation in the unit and defined by plant species with similar tolerance for depth and duration of flooding: (1) moist soil, (2) shallow emergent vegetation, (3) deep emergent vegetation, and (4) open water. We then defined four transects per unit, beginning each at the outer edge in each of the four cardinal directions around the unit and continuing them along a depth gradient toward the center of the wetland, until we encountered open water or until the vegetation became uniform. In the latter case, we limited transects to 100 m, and distances between transects were not fixed. We then measured the radius from the center of the lowest zone to the outer perimeter of each zone and estimated the area of each zone as $\pi(R_1^2 - R_2^2)$, where R_1 and R_2 are the zone's outer and inner radii. From these areas, we calculated the proportion each zone represented of the unit's entire area. We used the number of zones in each wetland unit as an indicator of its habitat complexity.

We estimated land use within a 10-km radius of each wetland unit (m^2), using the 2008 and 2009 cropland data layers for California (http://www.nass.usda.gov/research/Cropland/SARS1a.htm) with ArcMap 9.3 (ESRI, Redlands CA). Existing land uses were reclassified under 12 categories of agricultural and non-agricultural land use. We analyzed rice, corn, and other grains separately, as waterfowl forage on them more than on other crops (Ackerman et al. 2006, CVJV 2006).

Bird Surveys

By area searches (Ralph et al. 1993), we surveyed all birds in the selected wetlands from 4 to 13 times (mean 8.5) approximately once every 3 weeks. Experienced observers equipped with spotting scopes began all surveys within half an hour after local sunrise. We omitted birds flying over, unless they were foraging aerially, and did not broadcast recorded calls, so numbers of secretive marsh birds such as rails were underestimated.

Data Analysis

We grouped species by 11 guilds defined by shared foraging behaviors and similar environmental requirements (Hickey et al. 2008). Then we compared the richness and diversity of species by intensity of management, sub-basin, and time since restoration according to the Shannon–Wiener index, which is also a measure of entropy (uncertainty) that reflects differences in proportional abundances of birds. Smaller values indicate wider variation in proportional abundance of species within the community and dominance by one or a few species. For comparisons of the number of vegetation zones, water depth, and proportion of each vegetation zone by intensity of management we used a Kruskal–Wallis one-way analysis of variance.

Bird-Occupancy Models

We used the program Presence (version 3.1; United States Geological Survey, Patuxent Wildlife Research Center, Laurel, MD) to model site occupancy and distinguished between models by means of Akaike's information criterion corrected for small sample sizes (AIC_c; Burnham and Anderson 2002). Program Presence estimates the likelihood of detection from patterns of detection and nondetection over multiple visits to the site (MacKenzie et al. 2002). We selected covariates *a priori* on the basis of our observations in the field and previous research during a period including spring migration but before fall migration (Kahara et al. 2012).

We considered a site occupied by a guild if at least one species of the guild was detected, unoccupied if no species of the guild was detected on any visit. To identify the model with the lowest value of AIC_c (reduced model), we modeled probability of occurrence as a function of each covariate both individually and in combination. If in any given model this value was greater than in the reduced model, then we eliminated that variable from further consideration. If two of the retained variables were correlated (Pearson correlation coefficient $r \geq |0.7|$), we eliminated the variable with the higher AIC_c value. We ranked the models by AIC_c value and report the "best" model (lowest AIC_c value).

Table 1 Size and Time since Restoration of Restored Wetlands Surveyed in California's Central Valley, 2008 and 2009

Intensity of management	*n*	Average size (ha, ±SE)	*n* by years since restoration	
			<5 years	>5 years
Unmanaged	15	329 (7.4)	9	6
Intermediate	31	334 (4.9)	22	9
Intensive	26	31 (0.2)	11	15

RESULTS

We completed 508 bird surveys on 61 sites in 2008 and 132 surveys on 11 sites in 2009. In both years the largest number of sites was managed at the intermediate level (43% in 2008, 45% in 2009), followed by intensively managed (36, 36) and unmanaged (21, 18). Intensively managed sites were older and smaller than intermediate and unmanaged sites (Table 1). Sites managed at different intensities differed mainly in vegetation composition. Unmanaged sites had significantly more upland vegetation (average 9.4%) than either intermediate or intensively managed sites. Wetland vegetation covered an average of 8.1% of intensively managed sites and 11.3% of intermediate sites, more than three times that of unmanaged sites (3.4%). Intensively managed sites had the most shallow marsh vegetation (average 6.1%), though not much more than unmanaged sites (average 5.7%). At all three levels of management deep marsh vegetation covered the least area, most on intermediate sites (average 0.6%). Vegetation coverage (average 6.6%) and depth (4.5 cm) of water were greatest on unmanaged sites in the summer but were not significantly different.

Bird Data

Over the survey period, we recorded 174 and 112 species in 2008 and 2009 respectively (Table 2). These included 17 species currently listed as of concern in California or nationwide (Hickey et al. 2008). Most special-status birds favored older, intensively managed wetlands in the northern Central Valley (Table 3). Smaller values of the Shannon-Wiener index suggest a greater disparity in species' abundance in the Tulare sub-basin than in the other two sub-basins (Table 4). Occupancy and species diversity of upland birds were best described by the null model (including all covariates), indicating that the mean probability of use did not differ by wetland unit or could not be differentiated by the covariates we selected.

Covariates selected in the most parsimonious bird-occupancy models varied by guild (Table 5). Though management was included in some of the top ten models for wading birds, marsh birds, dabbling ducks, and aerial feeders, it was not the most important variable. Habitat complexity was the most important variable determining occupancy by wading birds, marsh birds, and shorebirds and an important variable for all wetland guilds except geese. The most important variable influencing goose occupancy was sub-basin, most geese being found in the Sacramento sub-basin. Moist

Table 2 Principal Bird Species[a] Recorded April–July 2008 and 2009 on Restored Wetlands in California's Central Valley, by Guild

Guild	Species (most abundant in bold)
Wading birds	Black-crowned Night-Heron (*Nycticorax nycticorax*), Cattle Egret (*Bubulcus ibis*), Great Blue Heron (*Ardea herodias*), Great Egret (*A. alba*), Green Heron (*Butorides virescens*), Snowy Egret (*Egretta thula*), **White-faced Ibis (*Plegadis chihi*)**
Marsh birds	American Bittern (*Botaurus lentiginosus*), Virginia Rail (*Rallus limicola*), Common Gallinule (*Gallinula galeata*), **American Coot (*Fulica americana*)**, Marsh Wren (*Cistothorus palustris*), Common Yellowthroat (*Geothlypis trichas*), Red-winged Blackbird (*Agelaius phoeniceus*), Tricolored Blackbird (*A. tricolor*), Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)
Geese	Canada Goose (*Branta canadensis*), **Greater White-fronted Goose (*Anser albifrons*)**, Snow Goose (*Chen caerulescens*)
Diving birds	Canvasback (*Aythya valisineria*), Redhead (*A. americana*), Ring-necked Duck (*A. collaris*), Lesser Scaup (*A. affinis*), Ruddy Duck (*Oxyura jamaicensis*), Pied-billed Grebe (*Podilymbus podiceps*), Clark's Grebe (*Aechmophorus clarkii*), Double-crested Cormorant (*Phalacrocorax auritus*), **American White Pelican (*Pelecanus erythrorhynchos*)**, Caspian Tern (*Hydroprogne caspia*), Forster's Tern (*Sterna forsteri*), Belted Kingfisher (*Megaceryle alcyon*)
Dabbling ducks	Wood Duck (*Aix sponsa*), Gadwall (*Anas strepera*), American Wigeon (*A. americana*), **Mallard (*A. platyrhynchos*)**, Blue-winged Teal (*A. discors*), Cinnamon Teal (*A. cyanoptera*), Northern Shoveler (*A. clypeata*), Northern Pintail (*A. acuta*), Green-winged Teal (*A. crecca*)
Shorebirds	Black-necked Stilt (*Himantopus mexicanus*), American Avocet (*Recurvirostra americana*), Black-bellied Plover (*Pluvialis squatarola*), Semipalmated Plover (*Charadrius semipalmatus*), Killdeer (*C. vociferus*), Spotted Sandpiper (*Actitis macularius*), Greater Yellowlegs (*Tringa melanoleuca*), Lesser Yellowlegs (*T. flavipes*), Whimbrel (*Numenius phaeopus*), Long-billed Curlew (*N. americanus*), Least Sandpiper (*Calidris minutilla*), Western Sandpiper (*C. mauri*), **Long-billed Dowitcher (*Limnodromus scolopaceus*)**, Wilson's Snipe (*Gallinago delicata*), Wilson's Phalarope (*Phalaropus tricolor*), Red-necked Phalarope (*P. lobatus*)
Aerial feeders	Western Wood-Pewee (*Contopus sordidulus*), Ash-throated Flycatcher (*Myiarchus cinerascens*), Barn Swallow (*Hirundo rustica*), Cliff Swallow (*Petrochelidon pyrrhonota*), Northern Rough-winged Swallow (*Stelgidopteryx serripennis*), **Tree Swallow (*Tachycineta bicolor*)**, Western Kingbird (*Tyrannus verticalis*)
Raptors	White-tailed Kite (*Elanus leucurus*), Northern Harrier (*Circus cyaneus*), Swainson's Hawk (*Buteo swainsoni*), Red-tailed Hawk (*B. jamaicensis*), American Kestrel (*Falco sparverius*), Great Horned Owl (*Bubo virginianus*), Burrowing Owl (*Athene cunicularia*), **Loggerhead Shrike (*Lanius ludovicianus*)**
Gulls	Ring-billed Gull (*Larus delawarensis*)

(*continued*)

Table 2 (*continued*)

Guild	Species (most abundant in bold)
Upland birds	California Quail (*Callipepla californica*), Wild Turkey (*Meleagris gallopavo*), Ring-necked Pheasant (*Phasianus colchicus*), Turkey Vulture (*Cathartes aura*), Mourning Dove (*Zenaida macroura*), Anna's Hummingbird (*Calypte anna*), Black-chinned Hummingbird (*Archilochus alexandri*), Nuttall's Woodpecker (*Picoides nuttallii*), Downy Woodpecker (*P. pubescens*), Black Phoebe (*Sayornis nigricans*), Warbling Vireo (*Vireo gilvus*), Western Scrub-Jay (*Aphelocoma californica*), Yellow-billed Magpie (*Pica nuttalli*), American Crow (*Corvus brachyrhynchos*), Common Raven (*C. corax*), Cedar Waxwing (*Bombycilla cedrorum*), Western Bluebird (*Sialia mexicana*), American Robin (*Turdus migratorius*), European Starling (*Sturnus vulgaris*), Northern Mockingbird (*Mimus polyglottos*), White-breasted Nuthatch (*Sitta carolinensis*), Bewick's Wren (*Thryomanes bewickii*), House Wren (*Troglodytes aedon*), Oak Titmouse (*Baeolophus inornatus*), Bushtit (Psaltriparus minimus), Wrentit (*Chamaea fasciata*), Horned Lark (*Eremophila alpestris*), American Pipit (*Anthus rubescens*), **Song Sparrow (*Melospiza melodia*)**, White-crowned Sparrow (*Zonotrichia leucophrys*), Savannah Sparrow (*Passerculus sandwichensis*), Grasshopper Sparrow (*Ammodramus savannarum*), Lark Sparrow (*Chondestes grammacus*), Spotted Towhee (*Pipilo maculatus*), California Towhee (*Melozone crissalis*), Orange-crowned Warbler (*Oreothlypis celata*), Yellow Warbler (*Setophaga petechia*), Wilson's Warbler (*Cardellina pusilla*), Western Tanager (*Piranga ludoviciana*), Black-headed Grosbeak (*Pheucticus melanocephalus*), Blue Grosbeak (*Passerina caerulea*), Lazuli Bunting (*P. amoena*), Bullock's Oriole (*Icterus bullockii*), Western Meadowlark (*Sturnella neglecta*), Great-tailed Grackle (*Quiscalus mexicanus*), Brewer's Blackbird (*Euphagus cyanocephalus*), Brown-headed Cowbird (*Molothrus ater*), American Goldfinch (*Spinus tristis*), Lesser Goldfinch (*S. psaltria*), House Finch (*Haemorhous mexicanus*), House Sparrow (*Passer domesticus*)

[a] Occurring at three or more sites, with five or more sightings.

soil, shallow emergent vegetation, and grain crops within 10 km were the most important variables contributing to occupancy by diving birds, dabbling ducks, and raptors, respectively. Local variables were more important than landscape variables for all guilds except geese and raptors. Wetland area, number of vegetation zones, proportion of shallow emergent vegetation, proportion of deep emergent, and grain crops influenced occupancy positively in all models in which they were included. Proportion of moist soil on site and corn in the adjacent landscape negatively influenced occupancy by diving birds and geese, respectively. Where year was included in best fitting models, it was related to occupancy negatively, likely because of the reduced survey effort in 2009.

Table 3 Criteria of Restored Wetlands Favoring Occurrence of Special-Status Birds in California's Central Valley, April–July

Species	Years since restoration	Management	Sub-basin
American White Pelican	<5	Intermediate and intensive	Sacramento
Loggerhead Shrike	>5	Intensive	Tulare
Long-billed Curlew	>5	Intensive	Sacramento
Northern Harrier	>5	Intensive	Tulare
Nuttall's Woodpecker	>5	Intensive	Sacramento
Song Sparrow	<5	Intensive	Sacramento
Whimbrel	>5	Intensive	Sacramento and Tulare
Yellow Warbler	>5	Unmanaged	Sacramento
Yellow-billed Magpie	<5	Intermediate	Sacramento

DISCUSSION

Wetlands provide multiple ecosystem services (Millennium Ecosystem Assessment 2005), for which restored wetlands in the Central Valley are often managed to provide only a small subset. Assessing the services restored wetlands deliver beyond those their management prescribes may help us create systems that more closely resemble their natural counterparts and are more resilient when the climate is unfavorable and resources are few.

Actively managed wetlands are used more often and support greater numbers of waterbirds than do unmanaged wetlands (Kaminski et al. 2006, O'Neal et al. 2010, Kahara et al. 2012), suggesting an important role for

Table 4 Richness and Diversity of Bird Species in Restored Wetlands of California's Central Valley, April–July, 2008–2009, by Intensity of Management, Sub-basin, and Time since Restoration

	n	Mean species richness (± SE, range[a])	Mean Shannon–Wiener index (± SE, range[a])
Intensity of management			
Unmanaged	15	12.97 (28.85, 37.15)	5.29 (6.02, 23.24)
Intermediate	31	13.81 (27.23, 37.25)	5.72 (4.34, 20.88)
Intensive	26	13.02 (1.20, 36.83)	6.01 (4.18, 16.50)
Sub-basin			
Sacramento	21	13.90 (1.46, 37.83)	6.35 (0.73, 23.26)
San Joaquin	6	17.98 (3.08, 20.00)	3.84 (1.25, 6.61)
Tulare	15	9.61 (1.39, 16.82)	4.38 (0.44, 5.28)
Time since restoration			
<5 years	42	11.82 (1.35, 37.83)	4.94 (0.60, 20.89)
>5 years	30	15.49 (1.89, 37.15)	6.84 (0.98, 23.26)

[a] Largest value minus smallest value.

Table 5 Factors Influencing Probability of Detection and Occupancy of Guilds of Birds in Restored Wetlands of California's Central Valley, April–July, 2008–2009

Guild	Detection probability	Occupancy
Wading birds	None	Number of vegetation zones
Marsh birds	Number of surveys	Extent of wetland, year, extent of nearby cultivated cropland, frequency of management, number of vegetation zones
Geese	None	Sub-basin, extent of corn nearby
Diving birds	Number of surveys	Extent of wetland, proportion of moist soil
Dabbling ducks	Number of surveys	Number of vegetation zones, proportion of shallow emergent vegetation
Shorebirds	Number of surveys	Extent of wetland, year, extent of grain crops nearby, number of vegetation zones
Aerial feeders	Number of surveys	Extent of wetland, year, proportion of deep emergent vegetation
Raptors	Number of surveys	Extent of wetland, extent of grain crops nearby
Upland birds	None	None

management. However, our results suggest that management carried out in the spring and summer is less important in determining bird occupancy than are characteristics of the site's habitat and adjacent land use. Occupancy by waterbirds and upland birds was more likely to be a function of a wetland's size, vegetation composition, and diversity. Although any wetland changes seasonally with germination of food plants and flooding, unmanaged wetlands are more likely than managed wetlands to remain consistent across seasons. Surprisingly, nearly half of all unmanaged wetlands we studied held more and deeper water over the summer than did intermediate or intensively managed wetlands. Therefore, lack of management does not preclude year-round water.

Though management of water and vegetation in most restored wetlands in the Central Valley follows a prescribed regime to create optimal habitat for wintering waterfowl, the timing and duration of these practices may be adjusted to cater to spring and summer bird use. For example, lowering water levels over 2 to 3 weeks between January and March may favor abundant seed production by plants such as smartweed (*Polygonum* spp.; Heitmeyer et al. 1989), but this schedule is too early for migratory shorebirds, whose numbers peak in April. A drawdown in April and May would provide shorebirds more habitat during migration. Alternatively, an even later drawdown (between May and June) would greatly benefit nesting shorebirds, particularly in the San Joaquin and Tulare sub-basins where there is less habitat for them than in the Sacramento Valley (Duffy et al. 2011, Kahara et al. 2012). Partial drawdowns and a greater diversity of hydrological regimes should maximize waterbird potential, and delaying vegetation management, such as eradication of undesirable plants by disking, burning, shredding, or mowing, would benefit a broad spectrum of nesting birds.

Landscape covariates appeared in many of the top bird-occupancy models but were not as important as characteristics of the site's habitat, as found by Valente et al. (2011). Bird–habitat relationships were consistent with previous studies, including relationships with extent of wetland (VanRees-Siewert and Dinsmore 1996, Naugle et al. 2001, Webb et al. 2010) and of shallow emergent vegetation (Kaminski and Prince 1984, Murkin et al. 1992, Webb et al. 2010). After extent of wetland, the presence of complex vegetation mosaics was the second most important factor contributing to occupancy. The guilds most likely to be affected by vegetation diversity were wading birds, marsh birds, dabbling ducks, and shorebirds. The gradient of vegetation zones observed at many of the restored sites creates structural heterogeneity and diverse food and habitat resources that may explain the diversity of bird species we observed under all management regimes. Vegetation diversity may be achieved through variation in topography in larger (>40 ha) wetlands or by maintaining multiple smaller (<4 ha) management units at different successional stages (Fredrickson and Taylor 1982).

Contrary to our expectations, grain crops in the adjacent landscape enhanced bird occupancy of wetlands, but this may have been a consequence of the timing of our study. In the fall and winter, flooded grain crops attract both wetland and upland species (Miller et al. 1989, Elphick and Oring 1998, Elphick 2000, Czech and Parsons 2002, Ma et al. 2010, Fleskes et al. 2012), possibly drawing them away from restored wetlands. Over the spring and summer, however, disturbance from increased agricultural activity may have the opposite effect and drive birds onto restored wetlands, elevating their importance as refugia during this period.

In the Central Valley, heavy dependence on irrigation for moist-soil management means that habitat availability for birds is a function not only of the weather but also of individual landowners' water rights and state regulations. Wetland managers in the drier southern Central Valley face greater challenges obtaining water than those in the north, which receives up to four times more rainfall. In the Tulare sub-basin, wetland managers have historically depended on groundwater, which is rapidly diminishing, becoming increasingly expensive, and contaminated (Hartmann and Goldstein 1994). The more frequent multi-year droughts forecast for the future may force the adoption of alternatives to intensive moist–soil management. Nevertheless, as we found, lack of management does not necessarily negate the value of restored wetlands, even if the effect on wintering waterfowl is severe. Creation of larger tracts with complex vegetation mosaics may allow unmanaged wetlands to continue to support a diverse avifauna in the spring and summer.

ACKNOWLEDGMENTS

We greatly appreciate the generous cooperation of all participating landowners and land managers. The staff of the Colusa, Kern, Pixley, Sacramento, and San Joaquin national wildlife refuges provided access and assistance. For their assistance with habitat and bird surveys we also thank Beth Werner, Shannon Chapin, Mary Burke, and Bryan Atkinson. J. Groves and C. Hickey provided valuable guidance. The manuscript was improved by the thoughtful comments and edits of Ron LeValley, Philip Unitt, and an anonymous reviewer. Funding for this research was provided by the NRCS Conservation Effects Assessment Project–Wetlands.

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Accepted 3 February 2016